

Future Trends in the Cell Site Planning For Capacity Enhancement

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ABSTRACT

In this paper, my aim is to provide an overview of the key challenges arising from Het Nets, Relay Nodes, SON, RRM, Co-MIMO, Cognitive Radio Network, DAS and highlight their importance. Recent research mainly concentrates on the aspect of interference mitigation, radio resource utilization, fairness, complexity and QoS. Improve the coverage as well as the capacity with high speed achieved by HETNET. Increase reliability and performance of the network achieved by RRM. Reduce the amount of manual process with the help of SON. Power allocation (PA) plays an important role in capacity improvement for cooperative multiple-input multiple-output (Co-MIMO) systems. Cognitive radio technology improves radio resource usage and minimize cost-flow problem. The reduction in energy consumption is achieved by considering fast power control.

Keywords: Het nets, Radio Resources management, SON, MIMO, Cognitive Radio Networks, Relay, and DAS.

INTRODUCTION

A recent trend has emerged with the heterogeneous deployment of low-power nodes (base stations) within macrocells thus forming a new communication network known as heterogeneous networks (HetNets). Recently, heterogeneous networks (HetNet) have been mostly studied as an effective approach to provide high network coverage and capacity. However, an important question about the energy consumption for HetNets is always raised due to the dense and random deployment of small-cells (e.g.: microcell, picocell and femtocells). The optimal energy efficiency of a two-tier heterogeneous network consists of a many small-cells and macro-cell under coverage performance constraints for different spectrum deployments (including co-channel and orthogonal spectrum deployments). The energy efficiency of the two-tier networks

With orthogonal spectrum deployment is better than that with co-channel spectrum deployment. The optimal density of small-cells for maximal energy efficiency is dependent only on the coverage performance of small-cells in orthogonal spectrum deployment. However, in co-channel spectrum deployment, the optimal density of small-cells for maximal energy efficiency is jointly decided by the coverage performance of both small-cell and macro-cell.

Limitation of the conventional macro cell approach is the presence of dead-spots and the poor indoor penetration, which results in indoor coverage, is drastically reduced. With these multi-tier networks, spatial reuse is potentially improved and achieve higher data-rates, while retaining the mobility and seamless connectivity of cellular networks [1].

In this paper, rest of the paper is organized as follows:-

CAPACITY ENHANCEMENT TECHNIQUES

- a) Het Nets
- b) RRM
- c) Self Organizing Network(SON)
- d) Co-MIMO
- e) Cognitive Radio Network
- f) Distributed Antenna System(DAS)

a. HETNET

Heterogeneous networks (Het Net) play a key role for future cellular networks. In the Het Nets, low power base stations of smaller coverage are present (deployed) inside the MACROCELL for traffic offloading. Mobile broadband traffic is growing frequently, people staying connected anywhere, anytime. Enhancing the user's quality of experience and network energy efficiency one size does not fit all, so HETNETS overcome these types of problems. HETNET provide high-performance backhaul and advanced traffic management. HETNET can help deliver high-quality and seamless mobile broadband experience to the users. The aim of the Het Net is to improve the network performance by Random distribution of lower power access nodes, such as femto and pico home eNBs (HeNB). While several studies in the literature have addressed various aspects of two-tier networking architectures, a combine solution that covers the challenging tasks of user association, interference management, resource allocation and network operation in Het Nets within a unified framework. The low-power nodes are generally known as small cells, e.g., microcells, picocells, femtocells and relay nodes (RNs) [6].

It has been reported that the information communication technology (ICT) infrastructure leads to 2% of CO₂ emissions and 3% of worldwide energy, which is expected to double by 2020. 0.2% of global energy is consumed by mobile communication networks in every year.

Femtocells and RNs have compared due to the following reasons:

1) Femtocells

- **Improved indoor coverage:** In the near future, it is predicted that approximately 50% of phone calls and 70% of data calls will originate from indoor environments. Unfortunately, indoor environments mostly suffer from high indoor building penetration losses. Result, the signal from the macrocell base station (BS) becomes weak or cannot be detected in these types of environments, which are known as coverage holes of the macrocell, shown in figure.
- **Reduced costs:** The deployment of small cells is considered to be more cost-effective compared to that of macrocells, since macrocell deployment has high installation costs. The installation of femtocells is based on a simple 'plug and play' method, and via an indoor broadband connection, the cost of backhauling a femtocell could be reduced.
- **Reduced power consumption:** By deploying small cells, a lower transmission power is required because the users can receive a stronger signal from the nearest small cell.
- **Improved QoS satisfaction:** More resources can be received by each user, results to better QoS.

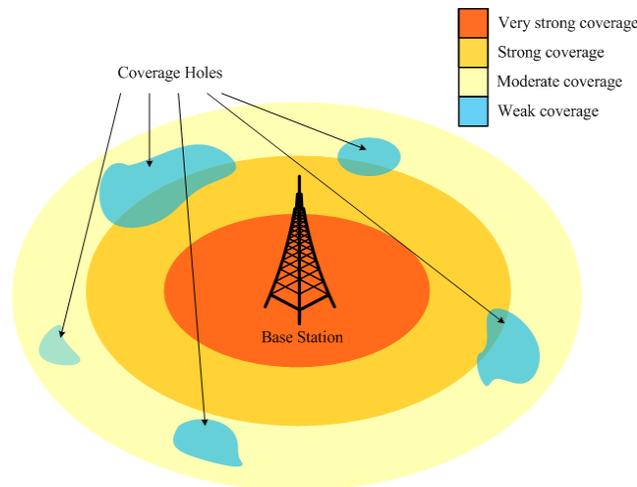


Figure1: Coverage holes in a macrocell [6]

2) Relay Nodes (RNs)

- **Improved cell-edge performance:** Mostly, the signal strength of a macrocell BS at the cell-edge area is weak due to multipath fading and distance-dependent path losses. So, deploying RNs at the cell-edge area would enhance the coverage and throughput performance.
- **Reduced costs:** The cost of deploying RNs is comparatively low to deploying eNBs.
- **Reduced power consumption:** Similar to femtocells, due to their close proximity the RNs can serve users with lower transmission power.
- **Increased user capacity:** As RNs can improve the channel conditions (mostly in the cell-edge area) and user capacity is also increased. Last but not the least, improved performance at the cell-edges.

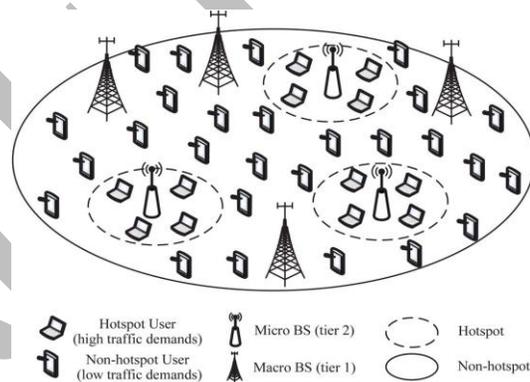


Figure2: System model and traffic demands spatial distribution [7].

Intercell interference (ICI) in both macrocell and smallcell networks decreases with a reduction in the transmit power (due to power control scheme) of the mobile users in the HetNets. The total interference of small cell network is higher than the macrocell. This is due to the large number of mobile users, increased number of small-cells and small radius of small-cells in the network. Reduction in interference can be achieved by employing a fast power control mechanism, similarly the ICI offered by the macrocell network decreases significantly with the increase in macrocell radius. The ICI of the HetNets strongly depends on the radius of the cell and power control mechanism [7].

FEATURES OF HETNET:

- Massive MIMO, 3D MIMO
- LTE/WiFi integration
- Device-to-Device communication (D2D)
- LTE as a public safety system

BENEFITS OF HETNET:

- Enriched capacity
- Spot-free coverage
- Boost capacity and system throughput many times more than a conventional network
- Improve the coverage
- High-speed
- High-capacity communications for specific hot-spot area
- Lower the cost
- Enhance the user experience

b. Radio Resource Management

The main RRM functions in a heterogeneous cellular system are:

1) Resource Allocation among Small Cells and Macrocells

In HetNets, resource allocation/partitioning among macrocells and small cells depending on which RRM approach are adopted. Resource partitioning include resource allocation between the backhaul link, the access link and the direct link (eNB-UE), and also depending on whether inband mode or outband mode is being operated. Among the cells, factors to consider in resource allocation include: interference, buffer size, number of users, resource demand, etc. Resource allocation usually takes place at the eNB.

2) Challenges and issues of RRM for hetnets

Many technical challenges and issues arise in RRM such as interference mitigation, fairness, QoS, radio resource utilization and RRM complexity.

3) Handover Management and Radio Admission Control

Decision-making can be based on whether a handover UE from a neighboring cell or the UE is a new UE originating from the cell itself. Handover management handles user mobility and handover i.e., the decision is made at the eNB, while signal strength measurements are obtained from the UE.

4) Packet Scheduling

Dynamic packet scheduling is one of the main RRM functions, with the objective of maximizing the cell spectral efficiency and cell throughput. The scheduling decision may be based on the QoS requirement of each radio bearer of the UEs, the interference level, the channel state information (CSI) or channel quality indicator (CQI) of the UEs, etc.

5) Interference Management

There are two types of interference present in a two-tier femtocell network: **cross-tier interference and co-tier interference**. Cross-tier interference is the co-channel interference generated between femtocells and macrocells. On the other side, co-tier interference is the co-channel interference that occurs between femtocells. This happens when the femtocells are densely deployed within a macrocell, resulting in coverage overlaps among the femtocells

[4]. Interference can be categorized into intracell interference, inter-RN interference and intercell interference. Intracell interference arises when the direct links, backhaul links and access links share the same set of PRBs. Inter-RN interference occurs when two adjacent RNs use the same set of PRBs.

6) Radio Resource Utilization

Current issues like limited spectrum availability and low spectrum utilization, the efficient utilization of radio resources is difficult for achieving such high peak data rates. Frequency reuse factor of one is the best solution to achieve the high performance targets. An RRM scheme has to be designed to minimize interference and maximizing the spectral efficiency.

7) Fairness

In many wireless networks or in multihop networks, fairness is an important issue of RRM. Mostly, the fairness issue in HetNets can be divided into global fairness and local fairness issues, where the global fairness issue is related to resource allocation between the direct and the backhaul-access links, and the local fairness problem corresponds to packet scheduling among UEs.

8) QoS Management

Improved QoS experience can be achieved when the number of UEs in femtocell is small. When some femtocells are build in public places like airports and shopping malls, where the number of UEs could be large and the available radio resources are limited then they may not be sufficient to fulfill the QoS requirements of each UE. So, QoS management becomes more challenging in het Nets, where large numbers of small cells are present and each small cell may have very limited frequency resources are available. Therefore, fulfilling the QoS requirements of every UE requires RRM solution.

BENEFITS OF RRM:

- Optimal capacity, reliability and performance
- Clients enjoy a seamless, trouble-free connection throughout
- Continually monitor the network for noise and interference problems

c. Self-Organizing Het Nets (SON)

Future generation cellular network will be able to self-organize autonomously without manual processes that type of cellular networks known as self-organization networks. Using RRM, the small cells should be able to perform self-optimization for radio resource allocation, interference coordination, load balancing, etc. This requires that all the Base Stations be aware of their system conditions and surrounding environments, which is a great challenge for the network operator to implement these type of networks with low complexity. Such networks enjoy lot of advantages like: reduced energy consumption, cost saving, efficient resource allocation, and seamless communications, etc.

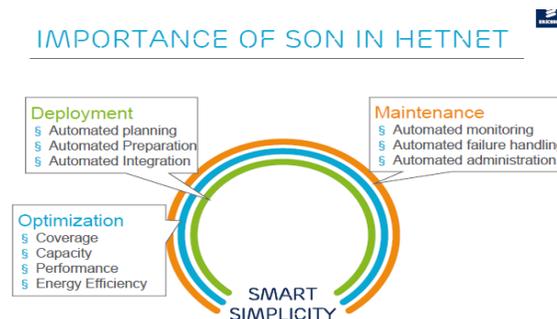


Figure 3: Self organizing Networks [8]

BENEFITS OF SON:

- Less prone to human error.
- Reduce the amount of manual processes involved in the planning, integration and configuration of new eNBs
- Faster network deployment and reduced costs for the operator

CHALLENGES OF SON:

- Discovery
- Routing
- Configuration
- Security
- MAC Layer adaptation

d. Co-operative MIMO (co-MIMO)

Currently, Co-MIMO has risen as a powerful alternative for improving communication coverage and cell-edge user's performance. To cooperatively transmit signals simultaneously, Co-MIMO enables neighboring transmit nodes with multiple antennas to form distributed MIMO. Therefore, the main objective is to provide maximize the capacity and coverage improvement of Co-MIMO system [8].

- **System model**

The system model is shown in Figure. Let us consider a Co-MIMO downlink system, where two neighboring BSs cooperate to transmit signals to one user. Each BS is connected with the center controller via zero-delay and high-capacity fiber. An information exchange between the center controller and each BS is error-free. Power allocation among data streams is performed at the center control. Then, the data information is delivered from the center controller to each BS. In this the two BSs cooperatively transmit the same data information to the user, so as to enhance the user's performance [8].

BENEFITS OF CO-MIMO:

- Time diversity
- Frequency diversity
- Space diversity

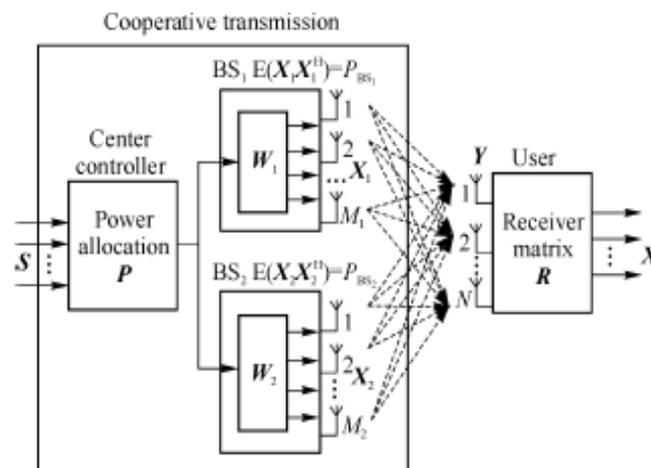


Figure 4: Co-MIMO system model [8]

e. COGNITIVE RADIO NETWORKS

Cognitive radio technology has been developed to improve radio resource usage of the wireless network environment. Recently, various wireless services, and the amount of mobile traffic is continuously and frequently increasing. To satisfy such a high demand for mobile communications, the capacity of mobile wireless networks has to be increased and requiring additional radio-frequency bands. However, most of the frequency bands suitable for mobile communications have already been assigned to existing wireless services, and the remaining bands are limited. Therefore, radio resource usage of the wireless network is a very important issue in the current wireless or cellular networks. Due to this, a network or a frequency band may be highly congested, while others have many available resources with low traffic. By dynamic use of the radio access networks or spectrum bands, the capacity and quality of the wireless systems can be highly improved.

- **Optimization of cognitive radio networks by centralized management**

In this optimization problem for finding the optimum BS selections L , the number of combinations increases exponentially with the increase in the number of BSs.

- **Optimization of cognitive radio networks by decentralized management**

In this, it is not easy to develop a centralized management network for large-scale wireless systems in which a centralized server manages a large number of wireless links by notifying all of the communicating terminals of the optimum selection. Consider the case in which there is no centralized server and the computation has to be performed using a distributed method [5].

BENEFITS OF CRN:

- Efficient Spectrum Utilization
- Multiple Channels Utilization
- Energy Efficiency
- Global Operability

CHALLENGES OF COGNITIVE RADIO NETWORKS

- Detection, False Alarm, and Miss-Detection Probability
- Hardware and Topology Changes
- Manufacturing Costs
- Clustering and Channel Selection
- Scalability and Power Consumption
- Quality of Service (QoS) and Security

f. DISTRIBUTED ANTENNA SYSTEM ARCHITECTURE (DAS)

Three main components: simplified access nodes, a fiber connection medium, and a central processing entity. In the following subsections are given below:

I. Massively distributed antenna system

DAS has few antenna elements, covering tens of square meters of space, to tens of antenna elements covering a few square kilometers of the targeted area. In DAS setting a single RAN engine simultaneously operates multiple RRHs. This is similar to classical MIMO system except that geographically distributed RRHs give additional degree of freedom, usually referred to as macro diversity. User has experienced path loss difference towards different antennas. It is preferable to direct all the transmission power to strongest RRH only [2].

DISTRIBUTED ANTENNA SYSTEMS

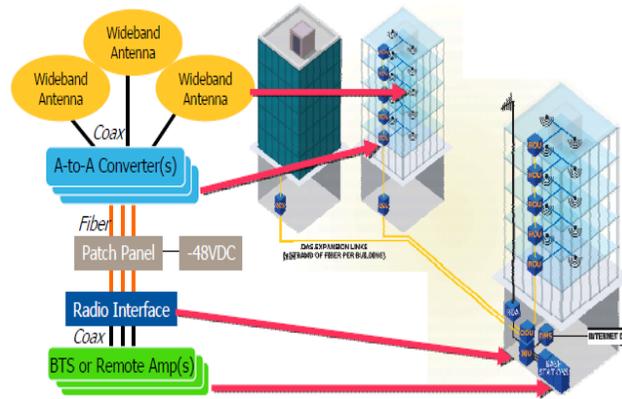


Figure5: Distributed Antenna Systems

II. Central processing entity

All the processing functionalities are focussed in the central processing entity, which enhance the system performance from several perspectives. In general, the interference among femtocells or between macro and femtocells can be high in two-tier Het Nets. The central processing entity allows joint processing of network-wide resource utilization and a lower interference level, which provides better system performance.

III. Fiber connection medium

The backbone of this network is fiber optic cables. It is connecting the central processing entity to each antenna element. Optical fiber itself is composed of two parts. First, a mechanism for electrical-to-optical conversion and vice versa according to their medium requirements. Second, the optical links will form a network that can utilize passive or active optical networking protocols. A passive optical network (PON) is a more cost-efficient implementation, which employs one pair of optical fibers for duplex transmissions between an antenna element and the central processing entity. If multiple transmit/receive antennas at an antenna element or multiple antenna elements are fed via a shared pair of optical fibers, wavelength-division multiplexing (WDM) techniques can further be exploited [6].

CHALLENGES OF DAS:

- Fail to optimize coverage in hard-to-reach places, typically in buildings
- Difficulty penetrating building materials such as concrete & brick, or new construction materials glass
- Disrupt the natural skyline of the campus or integrity of historic buildings
- Higher cost as a result of additional infrastructure required and Require greater number of antennas, although they are likely to be much lower in height.

ADVANTAGES:

- Better defined coverage and Fewer coverage holes
- Same coverage using a lower overall power

Based on these technologies that have presented in previous sections, the summary of table 1- "Qualitative comparison between different approaches for Hetnets with Femtocell" and table 2- "Current State of the Art" are summarize below:-

TABLE 1: Qualitative comparison between different approaches for Het nets with Femtocell

Approach	Link Direction	Complexity	Cross-tier Interference	Co-tier Interference	Spectral Efficiency	Fairness	Qos
Frequency scheduling	Downlink	Low	Low	Low	High	Moderate/High	Moderate
Cooperative	Downlink	Moderate	High	-	High	-	-
Frequency Reuse	Downlink	Moderate	-	High	High	Moderate	High
Femtocell Clustering	Downlink	Moderate	High	High	Moderate	Moderate	Low
Cognitive Radio	Downlink	Moderate	High	-	High	Low	High
Distributed Learning	Downlink	Moderate	High	-	High	Moderate	Low
Power Minimization	Downlink	Moderate	-	High	High	Moderate	Moderate

TABLE 2: Current State of the Art

Trends	Benefits	Challenges
Carrier Aggregation	<ul style="list-style-type: none"> • High data rate • Improved Capacity • Better coverage • Flexible spectrum utilization 	<ul style="list-style-type: none"> • Test setups may be quite complex • Simultaneous transceiver chains lead to inter modulation and cross-modulation within UE
MIMO	<ul style="list-style-type: none"> • Higher data rate • High efficiency 	<ul style="list-style-type: none"> • Antenna design and Coupling effects • Low latency • High throughput data interface between the central processing unit and the multiple receivers
SON/Smart Hetnets	<ul style="list-style-type: none"> • Improved coverage • Improve energy efficiency • Reduce OPEX and CAPEX • Improved Quality of experience • Faster network deployment • Better overall network capacity 	<ul style="list-style-type: none"> • Configuration • Discovery • Routing • MAC layer adaptation • Security
Interference Management	<ul style="list-style-type: none"> • Lower Data usage cost • Better Coverage • Better Quality experience • Improve energy efficiency • Better overall capacity 	<ul style="list-style-type: none"> • Designing optimized cell association and power control methods for multi-tier networks • Designing efficient methods for cooperation and coordination among multi-tiers • Designing efficient methods to support simultaneous association to multiple BSs
Relays and DAS	<ul style="list-style-type: none"> • Better coverage • Better Quality of experience • Faster network deployment • Improved Energy efficiency 	<ul style="list-style-type: none"> • Designing and Management • Higher cost as a result of additional infrastructure required • Require greater number of antennas, although they are likely to be much lower in height

In the technology survey of capacity enhancement above these techniques contribute, and still to keep in pace with the increasing the demand of mobile data requirement in future, new directions has to be explore

CONCLUSION

This paper investigated the efficiency of the two-tier Het Nets. Illustrate the effect of the worst and the best case interferences in the two-tier network of Het Nets. MIMO, SON, DAS, these are the key performance indicators in designing and planning of the future Het Nets [7]. For real Co-MIMO systems, each transmit node has its own power amplifier. In this paper, an optimal power allocation scheme in Co-MIMO systems under individual power constraint for each transmit node. Mobile networks of the future will need great capacity and better user experience, and Het Net is how we get there [8]. Finally, it can be concluded that the research area for HetNets is still subject to many challenges, some of which have been highlighted in this paper [4].

Problem in heterogeneous wireless networks, namely, traffic load balancing, which is a typical optimization problem that seeks to avoid traffic congestion. In order to improve the radio resource usage of the wireless networks, there are various other factors that should be optimized. Important remaining issue has clarified in previous section. The better approach will be decided on the basis of various factors of the network such as the signaling delay, the network size, and so on [5].

FUTURE WORK

The aim is to present innovative researches, methods and techniques related to the HETNETs and their applications. Due to advances in networking technologies, and especially, in wireless and mobile communication technologies, and devices with different networking interfaces, the networking systems are moving towards the integration of wired and wireless resources leading to Heterogeneous Networking Environments and Technologies (HETNET). The integration of various networking paradigms into one networking system is requiring new understandings, algorithms and insights, frameworks, middleware and architectures for the effective design, integration, and deployment aiming at achieving secure, programmable, robust, transparent and ubiquitous HETNETs.

For future research, analyze more complex resource allocation strategies such as interference alignment to further improve system capacity.

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